

GEOSTATIONARY SATELLITE POSITIONING BY DLR/GSOC OPERATIONS AND MANAGEMENT METHODS

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Abstract - Starting with a short description of the GSOC (German Space Operations Center) and its role within the wider framework of the research institute DLR, this paper provides a review of the geostationary telecommunications satellites positioned by the GSOC. The paper then proceeds to describe the evolution of the operations and management structures and methods which have been effectively used to accomplish these missions.

1. INTRODUCTION

During the past 25 years the DLR-German Space Operations Center (GSOC) has operated an extensive variety of satellites. In particular, GSOC has specialized in the positioning and operation of Geostationary Communication Satellites and has successfully delivered and maneuvered eleven geostationary satellites to their on-station positions.

This paper describes the operational and management methods which have developed over the years to support the positioning of geostationary satellites. In particular this paper focuses on the following major topics:

- the role of GSOC within the DLR and its responsibilities in the preparation and execution of national and international spaceflight projects.
- the current track record in the field of communication satellites reaching from the German/French SYMPHONIE program through to the EUTELSAT II F4 mission. The paper discusses the specific features of the different programs and the special requirements that these missions put on the ground segment facilities and staff.

- the management structures of the different programs and its relationship to the GSOC project organization.
- the organization of LEOP (Launch and Early Operations Phase) Services as it is performed at GSOC. This is presented using the example of the EUTELSAT II program.

2. THE ROLE OF GSOC WITHIN DLR

The German Aerospace Research Establishment (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt - DLR) is Germany's largest research institution for the engineering sciences and employs over 4.500 people at seven Research Centers.

Situated on the DLR site at Oberpfaffenhofen near Munich, the German Space Operations Center (GSOC) has over the past 25 years provided services for the operation and support of a wide variety of manned and unmanned space missions. Currently the GSOC is responsible for the German National space program and in addition supports both ESA and NASA activities.

The current generation of DLR spacecraft control systems and facilities have been developed and maintained over the previous 10 years with the specific requirements of multimission functionality. The implementation which has resulted, has proven the strategy to be both flexible and cost effective. This has subsequently enabled the DLR to use essentially the same software, systems and facilities to support a wide variety of spacecraft missions including manned missions, scientific missions and telecommunications spacecraft both in LEOP and routine mission phases.

The experience available through the GSOC is reflected in the wide variety of space missions which have been supported since its establishment and include:

- Geostationary Satellites
(SYMPHONIE, TV-SAT, DFS, EUTELSAT II);
- Interplanetary Missions
(HELIOS, GALILEO);
- Earth-Orbiting Scientific Missions
(AZUR, AEROS, AMPTE, ROSAT);
- Manned Spaceflight Missions
(FSLP, SPACELAB D1 and D2, MIR, COLUMBUS);
- Ground Station Support
(e. g. GIOTTO, EUMETSAT);
- Sounding rocket programs
(ARIES, TEXUS, MAXUS).

Currently the GSOC operates eight control rooms at the Oberpfaffenhofen site. This includes the original facilities and a new complex built to support manned space missions which has been equipped with highly modern facilities and systems. To date this new facility has been used successfully for the D2 mission in May 1993, and the MIR '92' E mission.

Since the start of 1994 the new complex has also been available and utilised for unmanned projects, i.e. conducting LEOPs, routine operations and for the support of scientific missions such as ROSAT.

At the DLR ground station in Weilheim the GSOC also operates two 15 meter S-Band Antennas and one 30 meter X-Band Antenna. In 1996 the facilities will be enhanced by the addition of a Ku-Band Antenna.

3. GEOSTATIONARY SATELLITES POSITIONED BY GSOC

GSOC has been active in the positioning of Geostationary satellites for over 20 years, starting with the first European efforts in this area - the German/French SYMPHONIE program. Since 1974 GSOC has successfully positioned eleven satellites in geostationary orbit, whereby a number of factors are particularly significant :

- In the time between mid 1989 and the end of 1992 a positioning was executed on average every 5 months.
- In mid 1990 three missions ROSAT, DFS-2 and EUTELSAT II-F1 were launched and supported during a three month period.
- GSOC is in the unique position to be able to support launches and transfer orbit injections from practically every type of rocket.

Since 1974 GSOC has been awarded various contracts to position satellites in geostationary orbit, to perform "In Orbit Tests", routine operations and also to support so called "Hot Standby"-operation phases (Figure 1).

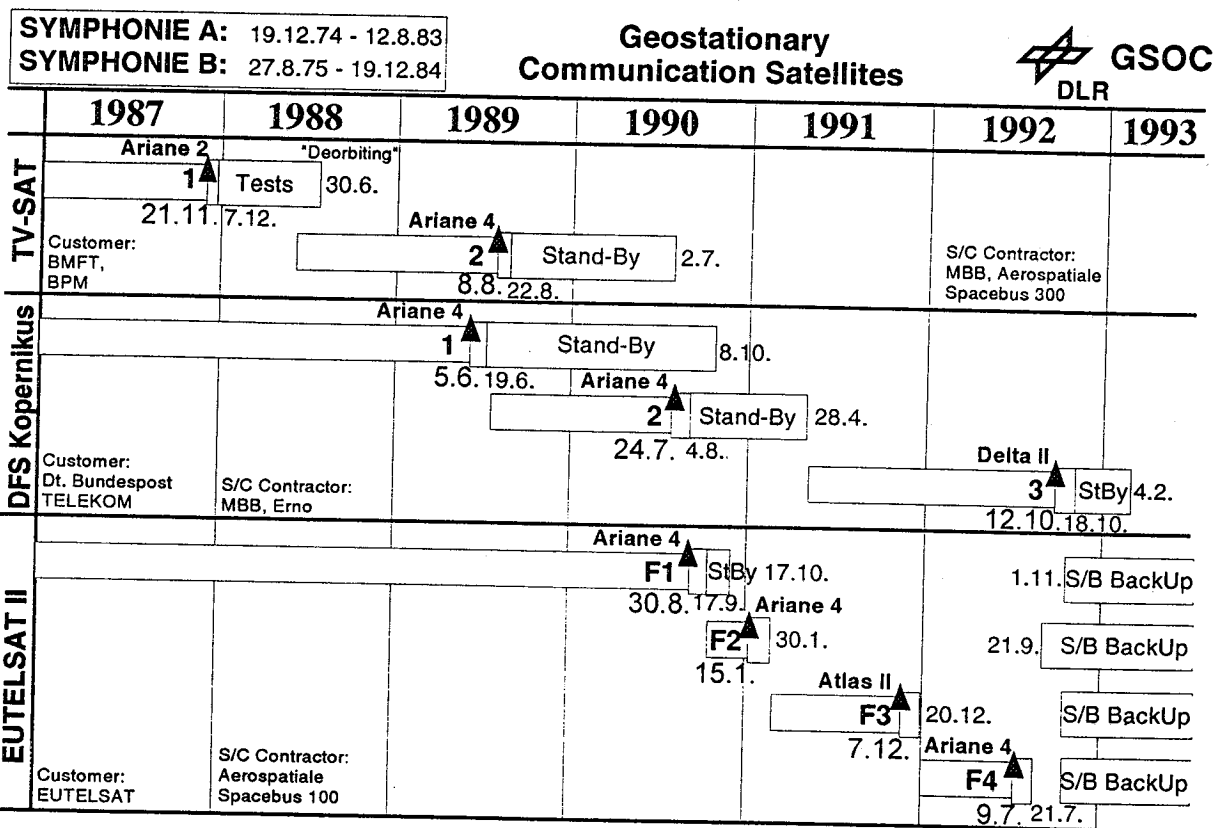


Figure 1: Communication Satellites positioned by GSOC

3.1 TECHNICAL & OPERATIONS ASPECTS

The following paragraphs outline the special technical and operational aspects of the various missions.

SYMPHONIE Program:

- SYMPHONIE A, Launch 19.12.74, DELTA
- SYMPHONIE B, Launch 27.8.75, DELTA

Following the launch, GSOC was responsible for the operations required to place the **SYMPHONIE** satellites at their dedicated positions in the geostationary orbit. For the first time in Europe, procedures for positioning a 3-axis stabilized geostationary satellite with optimized fuel consumption for routine operations and station-keeping were developed and successfully implemented. The on-station operation was executed by time and work sharing with CNES over a period of 10 years (the Satellite's designed lifetime was 5

years). Another significant factor for these missions was the fact that SYMPHONIE A/B were the first geostationary communication satellites to be brought into the so called "graveyard orbit" using the remaining fuel.

TV-SAT Program:

- TV-SAT 1, Launch 21.11.87, ARIANE 2
- TV-SAT 2, Launch 8.8.89, ARIANE 44 L

The **TV-SAT 1** project made high technical and operational demands on GSOC. Due to a technical malfunction of the satellite it was not possible to deploy one of the two solar pannels of the spacecraft. Despite this problem the spacecraft was successfully positioned in its geostationary orbital position of 19° W. During the positioning it was necessary not only to define modified maneuvers, but also to define new test procedures to analyse and find a solution to the problem. The complexity and size of the actual program undertaken was possible

only because of GSOC's existing engineering know how, the flexibility of the equipment used, and the ability to react rapidly to software- and configuration changes. Despite this, it proved impossible to deploy the solar panel and as a direct result the unopened solar panel prevented the operating ability of the Ku-Band Tx-antenna and subsequently any routine operation in Ku-Band.

In the following months TV-SAT 1 was used for test purposes to gather experience for the follow-up missions and at the beginning of May 1989, the on board thrusters were used to move TV-SAT 1 into a safety orbit 340 km above the geosynchronous orbit.

The **TV-SAT 2** project in contrast was a perfect mission. Using routine operational planning and optimisation methods the satellite was put into its geostationary position in a record time of 11 days. Following "In-Orbit Tests" the responsibility for the routine operations was transferred step by step to the Deutsche Bundespost TELEKOM.

DFS Kopernikus Program:

- DFS-1 Kopernikus, Launch 5.6.89, ARIANE 44L
- DFS-2 Kopernikus, Launch 27.7.90, ARIANE 44L
- DFS-3 Kopernikus, Launch 12.10.92, DELTA II

After injection into transfer orbit by an ARIANE 44L, the **DFS-1** and **DFS-2** satellites were positioned in the required geostationary orbit by the GSOC operations team using the classical 3-impulse method. Following the positioning, GSOC executed the In Orbit tests for the Deutsche Bundespost TELEKOM, and subsequently undertook routine operations for a period of one year. Following the step by step transfer of the routine operations to the TELEKOM control center at Usingen, the GSOC team remained in "Hot Standby" for a period of three months, ready at any time to resume routine operations if required.

The launch of **DFS-3** with a DELTA II rocket meant a new mission profile when compared with an ARIANE or ATLAS launcher. With the continual development of the maneuver strategies, it was possible to create a maneuver sequence which

allowed positioning to take place in the absolute record time of six days.

EUTELSAT II Program:

- EUTELSAT II-F1, Launch 30.8.90, ARIANE 44LP
- EUTELSAT II-F2, Launch 15.1.91, ARIANE 44L
- EUTELSAT II-F3, Launch 7.12.91, ATLAS II
- EUTELSAT II-F4, Launch 9.7.92, ARIANE 44L
- (EUTELSAT II-F5, ARIANE failure 24.1.94)

With the positioning of **EUTELSAT II-F1** a high standard system for LEOP Services was used. With this system the high level of EUTELSAT requirements were met in particular the redundancy concept. The mission operations experience gained from earlier positioning activities (SYMPHONIE, TV-SAT and DFS) were used effectively and the satellite was positioned within the shortest possible time. In addition specially developed optimizing programs allowed the fuel consumption to be minimized, thus extending the operational life time of the satellite. 17 days after launch the EUTELSAT II-F1 satellite was handed over to the customer for utilization. For a further 4 weeks GSOC was available for "Hot Standby" operations.

During the "Station Acquisition Phase" of the positioning of **EUTELSAT II-F2**, new strategies and manoeuvres were performed (using specially developed colocation software) in which the satellite flies around the operational control boxes of other geostationary satellites to avoid collisions.

The launch of **EUTELSAT II-F3** using an ATLAS II rocket meant a new challenge for GSOC. The satellite was launched into an orbit outside the geostationary orbit (42.000 km). An additional perigee orbit maneuver was necessary, and was performed for the first time. The development of new operational procedures and the continuous development of the maneuver software allowed the GSOC operations team to meet the customer's request to position the satellite within two weeks.

EUTELSAT II-F4 was a normal routine positioning for GSOC. The satellite was handed over to the EUTELSAT Satellite Control Center in Paris after 11 days.

3.2 PROGRAM MANAGEMENT STRUCTURES

This section provides a short overview of the relationship between the program management structures of the overall program and the management structure of the GSOC. The section reviews the interfaces and how the two management structures worked together (Figure 2).

As part of the Ground System Project Group, GSOC was responsible for the German part of the Ground System and thus was responsible for the preparation and execution of the positioning of the satellites and subsequently for the routine operations. In a similar fashion, CNES / Toulouse was responsible for the corresponding French tasks.

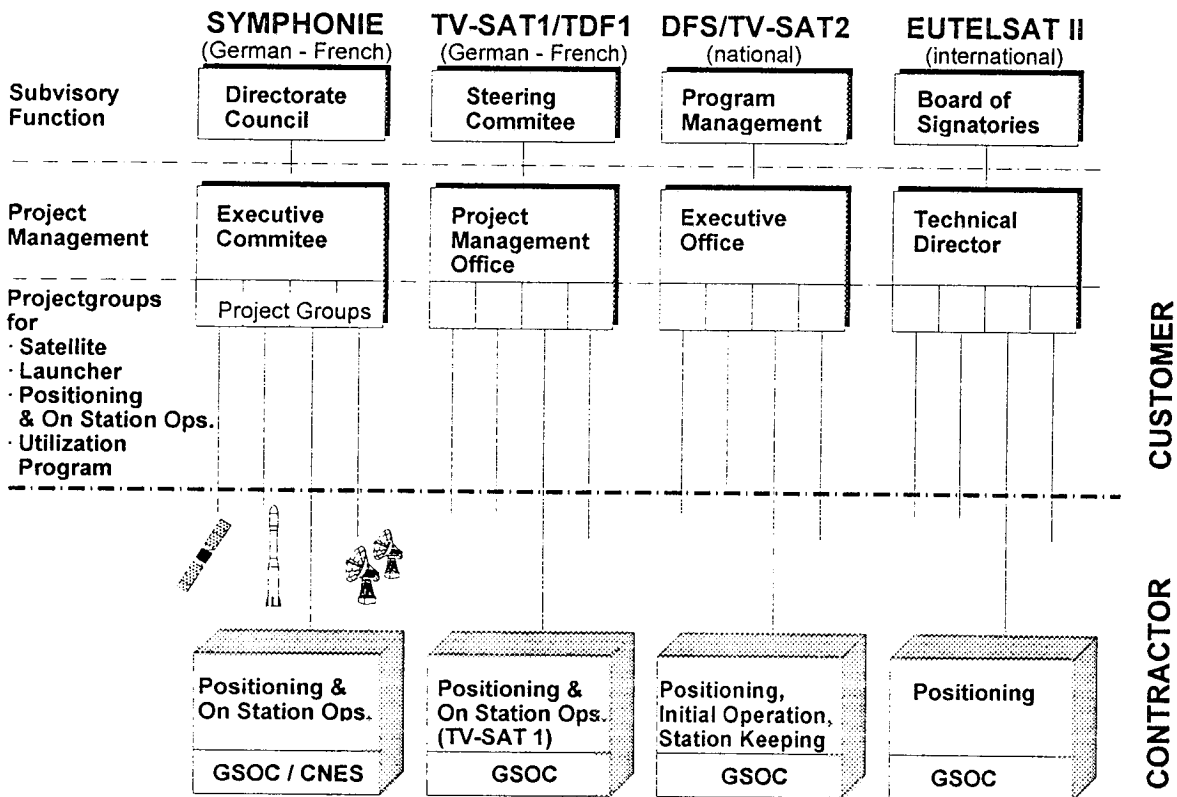


Figure 2: Program Management Structures

SYMPHONIE Program:

The German-French SYMPHONIE program was executed as a joint German French program, whereby all organizational units were manned with a mixture of French and German staff. The project organization was a bilateral management structure with three levels :

- The Directorate (as Subvisory Function)
- The Executive (as Project Management)
- The Project Groups (for specific work items)

TV-SAT 1 / TDF 1 Program:

Similar to SYMPHONIE, the Management Organization of the joint German-French TV-SAT 1 / TDF1 project contained three layers. The general guide lines for the execution of the project were defined by a steering committee. This steering committee was reported to by the bilateral PMO (Project Management Office) underneath which the Project Groups were organized for the actual execution of the project. This project office represented the interface to GSOC for all contractual and technical matters as far as it responsibility for the Ground System was concerned.

DFS / TV-SAT 2 Program:

The TV-SAT 2 and DFS projects were national programs and the management lay solely in the hands of the Ministry for Post and Telecommunications (BPM). The program management was created as an Executive office for the management of national satellite systems under the FTZ (Fernmeldetechnisches Zentralamt). GSOC, being responsible for the positioning, had interfaces to the necessary project groups for technical matters, and directly to the Project Management at the FTZ for contractual matters.

EUTELSAT II Program:

The European Telecommunications Satellite Organization EUTELSAT is an international Organization with members in 46 countries. The highest control organization is the Board of Signatories. The project groups and project management report to the General Director who in turn reports to the Board of Signatories. The project management is responsible for the execution of the decisions made by the board, and also for the coordination of the complete program - i.e. also for the "LEOP-Services".

3.3 ORGANIZATION OF THE "LEOP - SERVICES" WITHIN GSOC

This part of the paper uses EUTELSAT II to describe not only the project organization, but also the Mission Operations themselves. The organization structure shown in figure 3 has been implemented since TV-SAT and has been successfully used for all follow-up programs. Within this project organization the DLR key persons are responsible for both the preparation and also for the execution of the mission.

The "LEOP-Services" Project Manager has the overall responsibility not only for the preparation phase (ground segment implementation), but also for the completion of the positioning where he performs the role of Mission Operations Director (MOD).

The Project Manager is supported by a Project Administrator primarily for project control but also for financial and contractual matters. In addition the project management is supported by an independent Quality Assurance Manager.

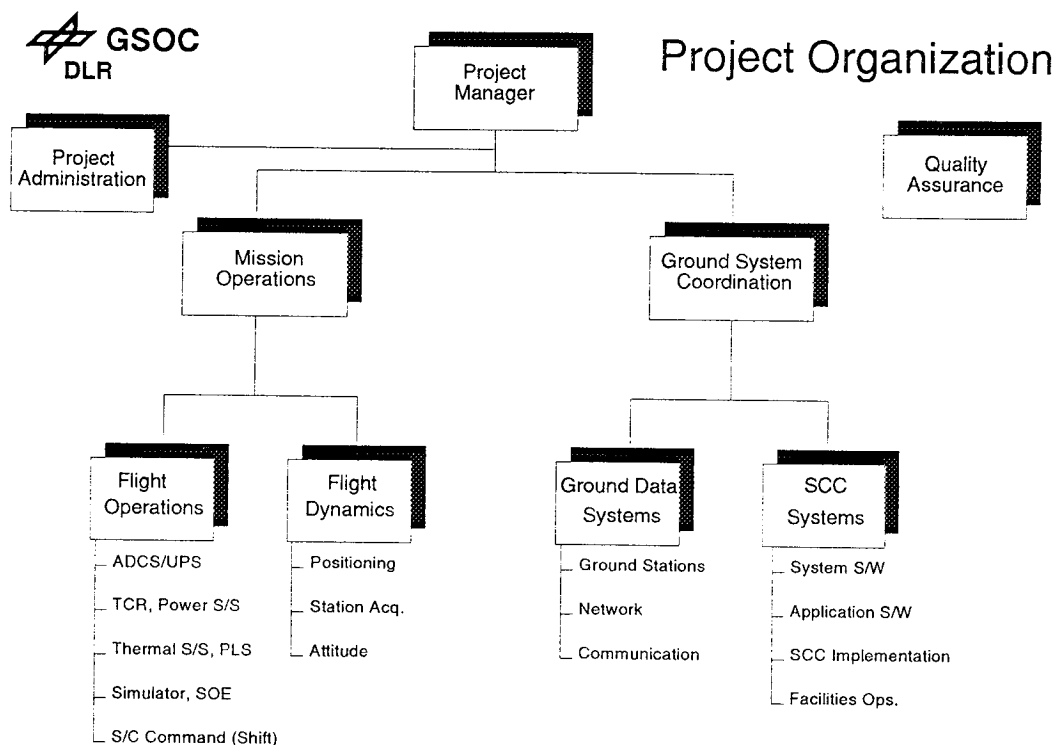


Figure 3: DLR / GSOC Project Organization for LEOP Services

Reporting directly to the Project Manager is the Mission Operations Team Lead (MOTL). Together with the Ground System Coordinator, the MOTL coordinates the work of the Team for the preparation and execution of a mission.

The DLR Mission Operations Team is created from Satellite and Ground System specialists who are allocated to the project from the various specialist departments of the DLR. This team of experienced Flight Dynamics, Flight Operations and Ground System Engineers is responsible not only for the preparation, but also for the execution of the mission.

As a direct result of this change to the structure, the project achieved a strongly subject orientated organization which provided better monitoring of the mission preparation and execution. The internal project monitoring with respect to the Mission Operations Team was much improved. The Mission Manager was hence released from this task and was able to focus his activities on the flight operations for the space segment. This becomes more important during the execution of the mission as the Mission Operations Team Leader is closely involved in the decision making process of the mission execution (see also Figure 4)

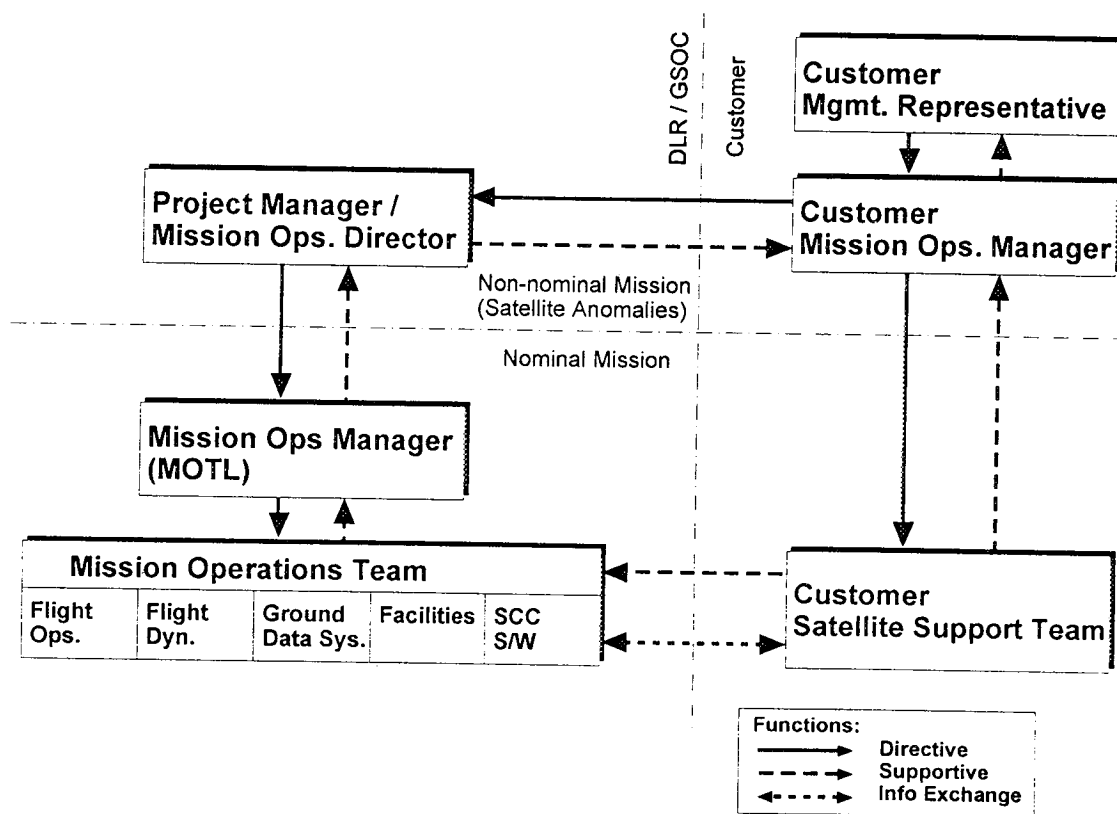


Figure 4: Organization of Mission Operations

Experience gained during the execution of the EUTELSAT II project allowed the refinement of the management structure, and more specifically determined the need for a Ground System Coordinator at the project level who provided direct assistance to the Mission Operations Team Leader.

The organigram (Figure 4) shows the principals of the organization of Mission Operations, whereby the interfaces for operational matters between the customer and contractor are also portrayed. Figure 4 shows how a positioning would be executed in close cooperation between GSOC and the customer.

As the Contractor, GSOC manages the mission under the control of the Mission Operations Team, lead by the Team Leader (MOTL). The mission is executed according to the Flight Plan which includes all nominal satellite operations together with a selection of predefined contingency procedures.

The customer is represented by the Customer Management Representative, Customer Mission Operations Manager and Customer Satellite Support Team.

The Customer Management Representative is the on site customer representative. He is responsible for the regulation of all mission related tasks including contractual matters as far as they relate to the responsibilities of the Customer Mission Operations Manager.

The Customer Mission Operations Manager follows the execution of Mission Operations, authorises the execution of emergency procedures and gives directives in the case of non nominal behaviour of the satellite. He is the only person who is authorised to give directives to the the DLR Mission Director or to the Customer Satellite Support Team.

The Customer Satellite Support Team, which is created from experts from the customer and the satellite manufacturer monitors the execution of the mission and compares the actual with the expected behaviour of the satellite. In case of non-nominal of the satellite, the Satellite Support Team provides the Mission Operations Team with inputs to correct the failure.

If the Mission Operations Team or the Satellite Support Team determine non nominal behaviour which is not covered by the Flight Plan, a special procedure has to be produced to cater for this behaviour. These special procedures are regarded as extensions, changes or adaptations to the existing Flight Plans and are produced in the form of "Recommendations". After release by the Customer Mission Operations Manager and the DLR Mission Operations Director, they are passed to the Mission Operations Team Leader (MOTL) for execution.

4. SUMMARY

Starting with SYMPHONIE, GSOC has been careful to systematically review and update the operational and management procedures and methods applied to positioning projects.

This approach has allowed the development of a set of standard geostationary positioning procedures and working methods which are optimised for modern communication satellites. These procedures and working methods have proved themselves during successive positioning activities.

From SYMPHONIE to the current series of EUTELSAT II spacecraft, the experience gained and retained over many years has been continuously used to both improve the ground operations facilities and also to enhance the operational capacity of GSOC specifically in the domain of geostationary satellite operations.

GSOC has proved its capability to adapt a variety of technical and management constraints as well as different contractual relationships.

The LEOP team at GSOC is able to react quickly and effectively to the most varied customer requests in a responsive and unbureaucratic fashion.

In this way the GSOC is in the position of being able to adapt its systems and operations to support practically any customer and any spacecraft manufacturer.

REFERENCE:

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